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LEAF SPRING MADE OF FIBER-REINFORCED RESIN

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16. Abstract  This patent pertains to a leaf spring made of a matrix reinforced by at least two types of reinforcing fibers with different Young's modulus. At least two layers of reinforcing fibers are formed by partially arranging the reinforcing fibers toward the direction of the thickness of the leaf spring. A mixture of different types of reinforced fibers is used at the area of boundary between the two layers of reinforced fibers. The ratio of blending of each type of reinforced fiber is frequently changed to eliminate the parts where discontinuous stress may be applied to the leaf spring. The objective of this invention is to prevent the rapid change in Young's modulus at the boundary area between each layer of reinforced fibers in the leaf spring.			
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## DETAIL

### 1. Name of the invention

Leaf spring made of fiber-reinforced resin

### 2. Scope of the patent application

A leaf spring is made of matrix resin reinforced by at least two types of reinforcing fibers with different Young's modulus. At least two layers of reinforcing fibers are formed by partially and preponderantly arranging the reinforcing fibers with different Young's modulus toward the direction of the thickness of the leaf spring. A mixture of different types of reinforced fibers is used at the area of boundary between the two layers of reinforced fibers. The ratio of blending of each type of reinforced fibers is frequently changed in order to eliminate the parts where discontinuous stress may be applied to the leaf spring.

### 3. Detailed explanation of the invention

This invention concerns a leaf spring made of matrix resin reinforced by fibers. This invention particularly concerns the kind of leaf spring made of matrix resin reinforced by fibers that is specially formed to keep the area of boundary between the two layers of reinforced fibers from generating discontinuous stress.

A variety of methods to manufacture a leaf spring made of

resin reinforced by fibers has been proposed in the past. In commonly used prepreg method, two kinds of reinforcing fibers with drastically different Young's modulus, for example carbon fibers and glass fibers, are separately coated with resin of different types. Several layers of the reinforced fibers are formed together into one body using matrix resin. Each layer is bonded together using an adhesive agent and formed into a leaf spring. In the case of the kind of the leaf spring 1 shown in Fig. 1, Fig. 2 and Fig. 4, a clearly established boundary 2 exists between one layer of the reinforced fibers, for example the layer 1c of the carbon fibers C (shown in broken lines in the figures) and the other layer of the reinforced fibers, for example the layer 1G of the glass fibers G (shown in solid lines in the figures) so that the reinforced fibers of different kind will not be woven together within each layer of the reinforced fibers. The kind of the reinforced fibers is entirely different at both sides of the boundary toward the direction of the thickness of the leaf spring. Accordingly, the two adjacent layers, 1c and 1G, have drastically different Young's modulus E. In other words, the leaf spring made of resin reinforced by fibers 1 has the layer 1c of the carbon fibers C at the upper and the lower surface layer part and the layer 1G of the glass fibers G at the middle layer part. Clearly established boundaries 2 exist between each layer as shown in Fig. 4. The part of the discontinuous stress 3, in both tensile stress  $\delta t$  and

compressible stress  $\delta_c$  , was present at the boundary area as shown in Fig. 6. Because the Young's modulus  $E_c$  of the carbon fibers C is considerably less than the Young's modulus  $E_g$  of the glass fibers G, the stress  $\delta_t$   $\delta_c$  of the layer 1G of the glass fibers becomes low, and the same of the layer 1c of the carbon fibers C becomes extremely high all of sudden if the both layers are given the same level of stress  $\underline{\epsilon}$  .

The result of the above phenomenon is that the leaf spring 1 made of existing matrix resin reinforced by two kinds of fibers with different Young's ratio is easy to break at the part 3 that is weakened by the discontinuous stress.

This invention was made in order to improve the above shortcoming of the existing technology. The objective of this invention is to use a mixture of different types of reinforced fibers at the area of boundary between the two layers of reinforced fibers and to frequently change the blending ratio of each type of reinforced fibers in order to eliminate the parts where discontinuous stress may be applied to the leaf spring. In other words, rapid change in Young's modulus is prevented at the boundary area between each layer of the reinforced fibers.

More detailed information is provided next using examples of practical application shown in figures. In Fig. 3 and Fig. 5, the leaf spring 11 made of fiber reinforced resin (hereinafter referred to as FRP) is actually made of matrix resin 12 reinforced by at least two types of fibers which have

different Young's modulus (eg. carbon fibers C and glass fibers G). At least two layers (three layers in the example shown in the figure) are formed by partially and preponderantly placing the reinforced fibers C and G with different Young's modulus toward the direction of the thickness of the leaf spring 11. At the boundary area 13 between the carbon fiber layer 11C and the glass fiber layer 11G, a mixture of the reinforced fibers CG which is different from either the carbon fiber or the glass fiber is used forming the mixed fiber layer 11M. At the mixed fiber layer, the ratio of the reinforcing fibers C and G is frequently changed in order to eliminate the possibility of the discontinuous stress 3 that is common to the existing leaf springs. The carbon fibers C are shown in broken lines, and the glass fibers G are shown in solid lines in the figures.

The mixing of the reinforcing fibers C and G is accomplished according to what is known as the micro method during the filament stage of each type of fibers, not the piling of the fibers C and G during the stage of the prepreg.

The structure of this invention is as described above, and the effects of this invention are as follows. In case the carbon fibers C and the glass fibers G are used as the reinforcing fibers as shown in Fig. 3 and Fig. 5, mostly the glass fibers G is mixed near the glass fiber layer 11G of the mixed fiber layer 11M. On the contrary, the volume of the

glass fiber G becomes gradually reduced toward the carbon fiber layer 11C, and the volume of the carbon fibers C becomes rapidly increased near the carbon fiber layer 11c. Hardly no glass fibers are found near the carbon fiber layer 11c.

Accordingly, the quality of the fiber does not change drastically at the boundary area between two layers of reinforcing fibers. In other words, no drastic changes are seen in the Young's modulus  $E$  as well. Accordingly, discontinuity in the tensile stress  $\delta_t$  as well as the compressible stress  $\delta_c$  is eliminated, and as shown in Fig. 7, the change in the stress ratio toward the direction of the thickness of the leaf spring becomes moderate. Each stress  $\delta_t$  and  $\delta_c$  is increased at the mixed fiber layer 11M and becomes to be connected with the stress figure of the carbon fiber layer 11c.

As a result, breakage of the FRP spring caused by the stress discontinuity can be prevented.

The structure and the function of this invention have been explained so far. In conclusion, different kinds of reinforcing fibers are mixed according to the location within a leaf spring, and the mixture ratio is frequently changed in the preparation of a leaf spring made of matrix resin reinforced by at least two different kinds of fibers which have different Young's modulus. Accordingly, rapid change in the Young's modulus can be avoided at the boundary area between two layers of reinforcing fibers. As a result,



discontinuous stress at the boundary area between two layers of reinforcing fibers can be eliminated, and the strength as well as the life of the leaf spring made of FRP can be significantly improved.

#### 4. Brief explanation of figures

Fig. 1 shows a partial oblique view of a FRP leaf spring. Fig. 2, 4 and 6 show the existing examples. Fig. 3, 5 and 7 show examples of the practical application of this invention. Fig. 2 is an enlarged, oblique, cross-sectional view of the part A of Fig. 1. Fig. 3 shows the same part as Fig. 2. Fig. 4 is a partial cross-sectional view of the FRP leaf spring. Fig. 5 shows the same part as Fig. 4. Fig. 6 and Fig. 7 show the condition of the changes in the stress toward the direction of the thickness of the FRP leaf spring.

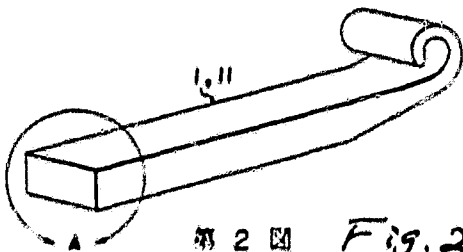
#### Key list:

3. discontinuous part of stress    11. a leaf spring made of FRP    11c. a carbon fiber layer, an example of one of the reinforced fiber layer    11G. a glass fiber layer, an example of the other reinforced fiber layer    11M. a layer of mixed fibers    12. matrix resin    13. a boundary part

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Fig 1 第 1 圖



第 2 圖 Fig. 2

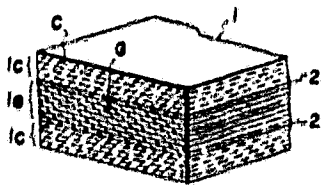


Fig. 3

第 3 圖

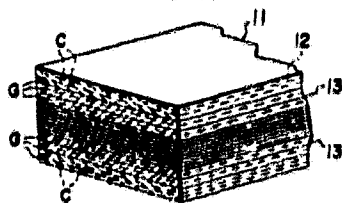


Fig. 4

第 4 圖

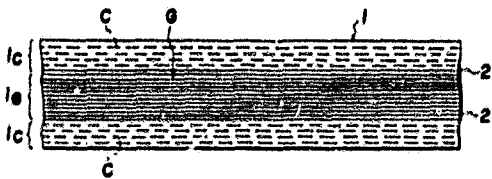


Fig. 5

第 5 圖

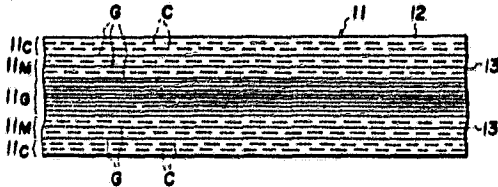


Fig. 6 第 6 圖

第 7 圖 Fig 7

